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L. O. HOWARD, Chief

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COTTON BOLL WEEVIL CONTROL BY THE USE OF POISON.[1]

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CONTENTS.

PRINCIPLES GOVERNING POISONING OPERATION.

IT SHOULD BE UNDERSTOOD that in poisoning for boll-weevil control extermination is not attempted or secured. The result aimed at is a sufficient reduction of the weevil infestation to permit maturing a full crop of cotton. This is brought about by tak-

[1] The investigations upon which this bulletin is based were in a sense the outgrowth of the work of Mr. Wilmon Newell, who published, together with Mr. G. D. Smith, in

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ing advantage of a combination of factors. In the first place, the cotton plant has a peculiar habit of putting on much more fruit than it is able to mature. About 60 per cent of the squares which appear on the cotton plant fail to reach maturity as bolls, and are shed at some time during their development. This does not mean, however, that the cotton plant is shedding 60 per cent of its fruit throughout the season. This shedding is comparatively slight early in the season and increases rapidly as the plants develop until it reaches the point where all the new fruit which appears is shed. It has been found that up to a certain point the fruit shedding due to boll-weevil attack merely takes the place of this perfectly normal shedding which would be encountered even if the weevils were absent.

The present system of weevil poisoning is intended merely to keep the weevils controlled to such a degree that they will not be able to do more than offset the normal shedding of the cotton plants. This means, generally speaking, that the weevils are permitted to multiply unmolested until they have become sufficiently abundant to puncture more forms than would shed normally. Poisoning is then started and every effort is directed toward holding the infestation below this point of danger until the plants have had sufficient time to develop beyond weevil injury as many bolls as they will be able to mature. Then poisoning is stopped and the weevils are allowed to resume multiplication. Experience has shown that remarkably large increases in yield frequently result from a comparatively slight degree of control for a short time during this critical period. It has also been very definitely determined, however, that this effect is cumulative and can only be secured by starting the applications at the right time and repeating them at the correct time interval. This is the reason the writers urge everyone contemplating weevil poisoning to decide upon conducting the operation as thoroughly as recommended or not to attempt it at all.

Circular 33 of the Louisiana State Crop Pest Commission, an account of experiments in controlling the boll weevil by the application of powdered arsenate of lead which were conducted in Louisiana during 1908 and 1909.

The studies of the U. S. Department of Agriculture on the subject of cotton boll weevil poisoning were first described in Department Bulletin 731, July, 1918. The present bulletin gives the results of investigations carried on since that time. It is to be followed by a detailed bulletin giving descriptions of the various tests and studies which serve as a basis for the recommendations made. The latter will also include a discussion of the contributions to the subject which have been made by various investigators for many years. The work has been conducted under the general direction of Dr. W. D. Hunter. The development of dusting machinery has been under the direction of Elmer Johnson, of the Bureau of Public Roads. The following have contributed to field and laboratory studies: F. F. Bondy, H. W. Lee, T. F. McGehee, R. W. Moreland, L. Z. Naylor, M. C. Rodgers, E. S. Tucker, W. B. Williams, and M. T. Young. The practical field tests have been rendered possible only by the hearty cooperation of the following: Prof. J. W. Fox, general manager, Delta & Pine Land Co. of Mississippi, Scott, Miss.; Mr. Alex. Y. Scott, general manager, Charles Scott's Delta Plantations, Rosedale, Miss.; and Mr. George S. Yerger, general manager, Maxwell-Yerger Planting Co., Mound, La.

KIND OF POISON TO USE.

In the various studies which have been conducted by the writers, nearly every known type of arsenical has been tested, but the first generally successful results were secured from the use of an improved type of arsenate of lead. This was soon replaced by calcium arsenate, and this chemical remains the best which has been found for this purpose so far. Tests were conducted with both liquid and dry applications, and it was found that with the liquid spray a slight degree of control was secured, but not nearly enough to make the operation profitable.

POISON SPECIFICATIONS REQUIRED.

When calcium arsenate was first tested it was found that the material as then prepared was not safe for use on cotton plants, owing to the injury caused by burning of the foliage. This was due to the excessive amount of water-soluble arsenic present. It was found that it was possible to make calcium arsenate without this high percentage of soluble arsenic, and the type which is now recommended for this work is absolutely safe for use on plants. Not all calcium arsenate, however, is of this safe type. Anyone attempting this work should purchase the calcium arsenate on specifications describing its composition. The specifications advised are as follows:

> Not less than 40 per cent arsenic pentoxid. Not more than 0.75 per cent water-soluble arsenic pentoxid. Density not less than 80 or more than 100 cubic inches per pound.

Calcium arsenate was almost unknown as an insecticide when these experiments were inaugurated, and its production had been attempted by only a few manufacturers. Recently, however, almost all insecticide manufacturers have undertaken its production. While its manufacture is comparatively simple, some experience is required to produce a thoroughly satisfactory material. Undoubtedly this difficulty will decrease rapidly as the manufacturers gain more experience in the production of calcium arsenate and the quality of the material becomes standardized, but for the present it is still advisable to make purchases only on the specifications recommended. If the total arsenic content is too low, the material is not sufficiently poisonous to control the weevil. If the proportion of water-soluble arsenic is too high, plant injury will be the result. Some lots of calcium arsenate have been found which killed the cotton plants within a few hours after application. It is also important to watch the density of the material very closely. If it is too heavy and runs much less than 80 cubic inches to the pound, it is not suitable for use in dry powdered form and will not produce the proper type of dust

cloud to cover the cotton plants thoroughly. Likewise, if the material is too light and runs much over 100 cubic inches per pound, it is blown away from the plants too rapidly by any light air currents.

SEND SAMPLES OF CALCIUM ARSENATE FOR ANALYSIS.

The best way to make sure of having the proper grade of calcium arsenate is to send a sample to the Delta Laboratory at Tallulah, La., for free analysis. This analytical service was started by the United States Department of Agriculture last season and if possible will be continued until the quality of calcium arsenate on the market becomes more uniform. Every cotton planter who purchases calcium arsenate for this work is invited to send in samples and he will be given an immediate report as to whether or not the material is satisfactory for use in cotton dusting. For this purpose it is advisable to take at least two or three samples from as many different packages. Probably the best plan is to sample 1 package in every 10 purchased. Half-pound samples should be taken from each and packed separately. The complete record of each sample should be packed with that sample, giving its full history, including name of manufacturer, when purchased, size and type of package, condition of material, analysis claimed by manufacturer, etc.

USE OF MIXTURES NOT RECOMMENDED.

The only chemical now recommended for boll-weevil poisoning consists of calcium arsenate which conforms to the specifications described. Attempts have been made to utilize various mixtures of arsenicals or dilutions of calcium arsenate. It is quite possible that some of these may prove satisfactory in the future, but with our present information it is advisable to adhere strictly to the use of calcium arsenate without the addition of any diluent whatever.

SUPPLY OF CALCIUM ARSENATE AND DUSTING MACHINERY AVAILABLE.

Prior to 1919 the production of calcium arsenate was so limited that it was difficult to secure a sufficient amount to conduct the experiments desired in this work. During 1919, however, interest in its production was stimulated to the point where probably 3,000,000 pounds were sold for cotton-dusting work. It appears that a fairly ample supply of calcium arsenate will be available for 1920. This is especially true in view of the probable shortage of dusting machinery. It has been found that successful results can not be secured unless special types of dusting machinery are utilized. These machines must be prepared for this particular purpose and their development has been considerably slower than that of the poison. At the present time the supply of machinery available is hardly sufficient to serve for the proper application of the poison already sold by the various manufacturers.

KEEPING QUALITIES OF CALCIUM ARSENATE.

Questions frequently are received as to whether or not calcium arsenate will deteriorate during long periods of storage. In some cases farmers purchased more than they could use during the past season and desired to hold over their surplus stock for use during the coming year. This is perfectly safe, as a properly made calcium arsenate should not deteriorate if stored in a reasonably dry place. Some lots have been kept at the Delta Laboratory for four years under normal storage conditions without the slightest deterioration. Moisture, however, even when it does not induce chemical deterioration, will cause calcium arsenate to cake so badly that it can not be utilized in the dusting machines.

EFFECT OF THE POISON ON MAN AND ANIMALS.

Questions are frequently asked regarding the effect of calcium arsenate on laborers and mules engaged in the poisoning operations. It is not nearly as dangerous as Paris green, as it does not have the caustic action characteristic of the latter. There is, however, a certain amount of danger attendant upon the use of any arsenical compound and reasonable precautions should be taken to protect the men and animals associated with it. Inhaling the dust should be avoided as far as possible. The most important precaution is that of personal cleanliness when using the material. The operators should be forced to bathe as soon as they complete the dusting work, and they should not be permitted to eat anything without at least washing their hands and face thoroughly. No injury to work stock has ever been experienced during operations, but it is safest to keep ordinary wire muzzles on all such animals in the poisoned fields.

The question of fall grazing of poisoned cotton fields is frequently raised. As a rule the last application of poison is made at least a month, and usually two or three months, before the cotton crop is harvested and the animals allowed to graze on the cotton fields. Even if no rains have occurred to wash the poison from the plants during this period, the amount of leaf shed has been so great that the foliage of the plant has probably been renewed several times and the plants utilized for grazing purposes are largely, if not entirely, new growth.

With regard to the danger to man involved in the use of calcium arsenate in the form of a dust cloud, it should be understood that arsenic may be taken into the body in three ways—by the mouth, by breathing, and by absorption through the skin. Ingestion or swallowing is the only manner which usually receives serious consideration, but in all probability it is the least important of the

three and can be avoided very easily by careful washing of the hands and face before eating or drinking.

Inhalation is a danger which is constantly present and is difficult to avoid except by the use of dust masks or some type of filtering arrangement which removes the dust from the air entering the mouth and nostrils.

Absorption undoubtedly is a very important means of taking arsenic into the human body. Even if extreme precautions are taken during dusting operations to avoid excessive direct contact with the poison supply, there is still a very considerable amount of poison dust settling all over the body from the air. This also has a decided tendency to adhere to the skin and "shed" water unless a strong lather is utilized, so a hasty rinsing in clear water should not be considered as a satisfactory means of removing the poison.

The danger of poisoning, although slight, should be considered. In the work conducted under the direction of the writers large quantities of calcium arsenate have been used by all sorts of laborers and generally with extreme carelessness. In spite of this, however, very few definite symptoms of even the slightest arsenical poisoning have been observed in connection with the field operations, and these few undoubtedly would have been avoided if proper precautions had been taken. Anyone using dry powdered calcium arsenate need not fear poisoning if he is reasonably cautious, but if any unexplained illness should develop during its use the possibility of poisoning should be borne in mind and a physician consulted. The preliminary symptoms of arsenical poisoning differ widely, but generally involve an intestinal and digestive disorder and are usually accompanied by some form of skin eruption.

An additional indirect danger to live stock should be considered. The cloud of poison frequently has a tendency to drift considerable distances. Conditions may be such that a dangerous amount of poison will drift into a neighboring pasture and injure some of the stock feeding on the grass. Stock should certainly not be allowed to graze on headlands and turnrows in fields which are being poisoned. The same applies to chickens, turkeys, and other fowls. The only fatalities the writers have observed in the course of poisoning work have been in the case of chickens and turkeys running in poisoned fields and picking in the débris covered with a heavy dosage of poison, where the machine had stopped and covered the ground rather thoroughly.

PLANT INJURY BY CALCIUM ARSENATE.

It is well to explain briefly the usual nature of arsenical injury to cotton plants, as there is a tendency on the part of inexperienced

operators to blame the poison for any form of plant disease. Plant injury by soluble arsenic ordinarily is termed "burning," and this word probably describes the appearance of the condition better than any other. The plants look very much as if they had been burned or scalded by some hot application, especially in cases of severe injury. The leaves and terminals droop and the young and more tender shoots wilt badly. This is followed very shortly by the death and drying of the most seriously injured tissue, causing lighter colored spots of dead tissue to appear over the leaves. In cases of mild injury this frequently involves only a sort of "shot-hole" effect over the leaves, but when the injury is severe the entire leaf is killed and falls from the plant in a short time. In still more severe cases the entire plant may die soon after the application.

One fact which should be borne in mind is that plant injury by soluble arsenic is generally very erratic and depends to a great extent upon the weather conditions prevailing at the time of and directly following the application. It will be noted in the specifications that a maximum limit of 0.75 per cent of water-soluble arsenic oxid is recommended. This does not mean that all material containing more than this amount of water-soluble arsenic will be injurious to the plants at every application. In reality, applications of calcium arsenate containing as high as 3 or 4 per cent of water-soluble arsenic frequently will not burn the plants, but it has been found from a large number of tests that any material running over the maximum limit established in these specifications will burn the plants seriously *when certain weather conditions are experienced.* The most dangerous calcium arsenates are those averaging about 2 or 3 per cent in water-soluble arsenic, as it is possible to make two or three applications of these before any plant injury is experienced.

The most dangerous conditions possible for plant burning are found during showery days when there are alternate showers and bright sunshine. On such a day the plants are moist and the atmospheric conditions ideal for making a satisfactory application of poison, but it has been found that if the water-soluble arsenic content of the poison used is the least too high it will produce very severe injury.

Another point which should be noted is that very serious loss from plant burning may result from a degree of injury which appears very slight at first glance. In many cases the injury is such that only a portion of the leaf surface is burned, comparatively little leaf shedding is caused, and the plants appear to recover completely in a day or two. In reality, however, a very slight degree of leaf burning may assume serious proportions because it causes sufficient plant disturbance to produce a heavy shedding of fruit.

In case of leaf injury the cause of which is doubtful, it is advisable to pick several affected leaves, pack them in a moist wrapper, and send them either to the Delta Laboratory or to the plant pathologist of the nearest State experiment station.

HOW TO APPLY POISON.

AMOUNT REQUIRED PER ACRE FOR EACH APPLICATION.

The quantity of calcium arsenate required for each application varies somewhat with the machinery utilized and with other conditions, such as the size of the plants, etc., but generally it has been found that at least 5 pounds per acre are necessary to make a satisfactory application. Where the machines are operated by experienced men, and especially by Government experts who have conducted this work for a number of years, it has been found that thoroughly satisfactory results can be secured by an average application of about 4 pounds per acre. But where the work is conducted upon a practical farm basis, the dosage used has averaged not less than 5 pounds per acre. Anyone attempting the operation for the first time is more likely to average in the neighborhood of 7 pounds per acre for each application. As calcium arsenate at present prices averages $0.25 per pound, any reduction in the amount required for each application is quite an important item, but to be on the safe side it is advised that until farmers are more thoroughly familiar with the operation the application should be excessive rather than too light. Properly conducted, the operation has a very large margin of profit and it is poor economy to risk this profit by attempting to save a pound or two of poison per acre.

The greatest factor for further saving in the amount of poison required lies in the improvement of dusting machinery. The figures which have been quoted above apply only to the machines which are now in use in this work, and it is hoped that by further improvement of this machinery it will be possible to reduce the amount. In fact, considerable progress has been made in this respect. When the first experiments were started with power dusting machines it was found impossible to control the weevils on an acre of cotton with less than from 12 to 15 pounds of poison dust. If the dust could be broken up into its finest particles and efficiently distributed, there would be enough material in about every 2 pounds of poison to dust an acre satisfactorily, but the present machinery is not equal to the task of delivering the dust in this form. This matter is being studied very carefully with the hope that further improved machinery can be devised.

CONDITIONS UNDER WHICH TO MAKE APPLICATIONS.

The time of day for making these applications is quite an important point. Thoroughly successful results can be secured only when every part of the cotton plant is absolutely covered by the fine particles of poison dust. It has been found that when the humidity is low and there is any breeze whatever, the dust cloud will drift away above the cotton plants and will not filter down and cover all portions of the plant surface. The best time to dust is when the humidity is high, the air calm, and the plants moist with dew, so that the dust will adhere readily. This condition is experienced generally only at night and thus it has been necessary to do nearly all of the dusting work during the night, early in the morning, or late in the evening.

It has been found that while the weevils can be controlled by applications made under unfavorable conditions, the results are generally very erratic and unsatisfactory, and at best can only be expected to hold the weevils in check without accomplishing any considerable diminution in their numbers. This, of course, means that the application must be repeated at very short intervals and makes the entire operation very risky. Therefore the best economy undoubtedly is to reduce the acreage allotment of the different machines to the point where it is not necessary to operate when the plants are dry or while a breeze is blowing. This will increase the outlay for machinery, but it makes the entire operation much safer. Operation under unfavorable conditions should be attempted only in case of absolute emergency and fields which have been treated under such conditions should be watched carefully to determine whether the requisite degree of control has been secured.

ARRANGEMENT OF POISONING SCHEDULE.

Those features of poisoning which include the number of applications, the time of starting, time of ending, and time interval between applications are of course exceedingly variable and depend upon purely localized conditions. But a number of fundamental factors govern these points which should be understood in order properly to plan the operation. In the first place, as has been mentioned, a certain degree of weevil abundance may be permitted without resulting in any reduction in the cotton crop. Furthermore, it is necessary to control the weevils and hold them below the point of injury for only a limited time until the plants have had an opportunity to set their maximum crop. Another important point which must be considered in this connection is the fact that poison reaches and kills only the adult weevils present in the field and has no effect whatever on the imma-

ture stages developing in the bolls and squares. These immature stages continue developing every day for a considerable period after the application is made. A single application may tremendously reduce the adult weevils present in the field at that time, but they will be replaced very quickly by the new generation which is maturing and emerging. Unless the applications are repeated at the proper time intervals, therefore, freshly emerged weevils will soon become sufficiently abundant to counteract all the benefit which may have been secured from the first treatment. In some cases one or two applications may control the weevils sufficiently to permit the formation of a considerable crop of young bolls, but unless these bolls are protected by continued applications the weevils usually will multiply with sufficient rapidity not only to infest the squares present but also to prevent these young bolls from reaching maturity.

SEASON FOR APPLICATIONS.

When it was first found possible to kill at least a certain percentage of the weevils by poisoning, it seemed that the best results would be secured by early season applications, thus deriving the double benefit of killing the weevils then present and preventing the development of their potential progeny. Consequently the first tests were almost entirely early season applications. But it was soon found that far more profitable results were secured by treatments later in the season. Thorough studies on this point have since shown quite definitely that by far the greatest profit is derived by making the applications at the critical time when the weevil injury is just beginning to exceed the normal shed of the cotton plants. Another important point is that the plant is fruiting so rapidly at this time that every day of retardation of weevil infestation means a great deal in additional cotton production.

The time when poisoning should begin has almost no relation to the size of the cotton plant and is purely a question of weevil abundance. Such factors, however, as the size of the farm or field involved will determine very largely the basis upon which poisoning can be planned. For example, in some districts where the cultivated areas are large and more or less consolidated, weevil injury is very evenly distributed, owing to the fact that the weevil adults emerging from hibernation in the spring usually concentrate on the first fields they reach and do not seriously infest the more distant fields until they have practically overtaken the fruiting of this near-by cotton. This condition is found in many portions of the cotton belt and is particularly pronounced in the district where the majority of this Department's tests have been conducted in the past, namely, the Mississippi Delta region of Louisiana, Arkansas, and

Mississippi. Here the plantations are fairly large, usually involving at least 500 acres of cotton in a single organization and frequently a much larger area than this. Under such conditions the poisoning is conducted upon the heavily infested fields with a twofold object: (1) To secure a reduction in weevil injury upon such fields, and (2) to reduce the numbers of weevils to the point where they will not migrate to the adjoining cotton. It has been found that by operating under such a system it is practically never necessary to poison the entire acreage. Complete economic control of the weevils for the entire acreage can be secured by concentrating on the most heavily infested cuts early in the season and thus preventing weevil multiplication and migration. This is particularly advantageous in that it distributes the cost of poisoning over a much wider area than would otherwise be the case. On the other hand, this system has the disadvantage, which will be discussed later, of requiring a rather complicated organization for conducting the poisoning work.

In districts where the cleared areas are smaller, or farther South where the weevil mortality is so low during the winter that hibernation is possible practically throughout the fields, a more generally distributed infestation is found early in the season and it becomes necessary to treat all fields alike. This is especially true in districts of small farms where the fields are comparatively small in extent and are more or less surrounded by weevil hibernation quarters. Under such conditions the only safe method of procedure is to poison the entire area alike, and this naturally requires a larger amount of poison per acre than is the case where it is necessary to poison only a portion of the crop.

TIME OF STARTING POISONING.

Many studies have been conducted upon the subject of determining the proper time for starting poisoning, but so far no thoroughly satisfactory simple method has been devised. In order to secure uniformity, in studies conducted during the past, a system of what is termed "percentage of infestation" has been utilized. This means the percentage of squares present in the field which are weevil-punctured. While this is fairly simple of determination, a certain amount of care is required if false conclusions are to be avoided. The method utilized throughout this work has been to examine a hundred or more squares at several points in a field—usually the four corners and the center, although this is not generally necessary under ordinary farming conditions. The percentage of these squares which are weevil-punctured is noted and serves as a basis for the poisoning operations. In this connection, however, it should be noted that weevil

injury is frequently distributed over the plants very unevenly, as the weevils display quite a pronounced tendency to concentrate on the upper portions of the plants, and percentage counts should be based on an examination of all squares on the plants rather than on squares examined at random on the upper portions. Naturally the percentage of injury which can be permitted varies with the stage of the cotton plant, but it has been found that usually, if 10 to 20 per cent of the squares are punctured early in the season, practically no harm results. The number of punctured squares gradually increases until later in the season as high as 60 per cent or more can be punctured without any reduction in crop yield. To put off poisoning until there is such a high percentage is not advisable, however, owing to the rapidity with which weevils multiply after they reach this point, and thus exhaust the square supply and start attacking the young bolls. The majority of the poisoning operations in the past have been planned so as to start when about 15 to 20 per cent of the squares were punctured and then to repeat often enough to prevent the infestation from getting above about 25 per cent until the crop is set and the bolls are safe from weevil puncturing. In some cases where it is particularly desirable to confine the weevils to a certain cut and prevent any chance of migration, it is well to start at a somewhat lower percentage and continue even later, but where the only object in view is the benefit to the particular cut poisoned, there is apparently little to be gained from starting applications before at least 15 per cent of the squares are punctured.

TIME INTERVAL BETWEEN APPLICATIONS.

The question of the time interval between applications is very important and one on which only conditional advice can be given, since it varies under different local conditions. In the past, once the applications were started they were generally made once a week as long as this seemed advisable or necessary. In reality, however, this selection of a time interval of one week was purely arbitrary and more recent results seem to indicate that in the majority of cases much better results can be secured by shortening this time interval. The effectiveness of a single application of calcium arsenate is decidedly limited in its duration. Its persistence on the plants naturally depends to a considerable extent on conditions prevailing at the time of application and immediately thereafter. In fact, while a very high percentage of control is secured during the first day of the application, this decreases the second day, and by the fourth day there is generally little or no effect. This short interval of effectiveness is due to two factors: (1) The poison is either washed or blown from the plants, and (2) new foliage is developed so rapidly that

after a few days a great deal of unpoisoned tissue is present, which thus reduces the chances of poisoning the weevil.

A four or five day time interval is best. This not only controls the brood of adults which were present when the applications were started, but also controls their progeny. Under average weather conditions the immature stages developing in the cotton forms at the time when an application is made will continue emerging over a period of at least 12 days. In other words, if the cotton can be kept poisoned thoroughly for a period of about 12 days, the weevils and their progeny are thoroughly controlled. Results vary of course with weather conditions but, generally speaking, two applications with a four-day interval have been found as effective as three or four applications with an interval of a week or more. If conditions are anywhere approaching normal about three applications with a four-day interval will usually reduce the weevil infestation to such an extent that it will be possible to stop poisoning, and in most cases this degree of control has been sufficient to persist during the remainder of the season. Another important point in this connection is that where a 7-day or 8-day interval is used and anything happens to interfere with the schedule, as it often will, the interval may be so extended that practically all control will be lost and the operation will become a complete failure; whereas, when the shorter interval is attempted, any mishaps will still leave the applications sufficiently close together to give a fair degree of control and the worst that can be expected is the necessity of making one or two extra applications.

It should also be taken into consideration that when the short interval is used the infestation can be permitted to become decidedly higher than would otherwise be safe. In other words, the control is so positive and the reduction of weevils so great that it is usually safe to permit the weevil practically to reach the point of becoming injurious to the cotton before making any application.

The machinery requirement must be considered very carefully in connection with the time interval between applications, as the acreage which can be handled by any particular machine is proportionately decreased as the interval is shortened. This of course increases the investment in machinery required per acre. But this cost is offset by the decrease in the number of applications necessary and the consequent reduction in cost of poison and labor. It is offset to an even greater extent by the better control secured and the resultant higher yield of cotton. Of course at present the machinery supply is decidedly short and machines are now high in price compared to what they will be in the future when their production is standardized, so it is quite a problem to determine just how much the acreage allotment for each machine can be reduced without making the ma-

chine investment per acre too high. On the other hand, it is undoubtedly the wisest policy to utilize methods which will give the greatest possible degree of control during the first few years when it is necessary for everyone to feel his way, more or less, in arranging the poisoning schedule. Consequently, it is urged that poisoning be attempted only under such conditions as will justify a sufficient machinery outlay to permit poisoning at about a four-day time interval.

NUMBER OF APPLICATIONS.

The question as to the number of applications is closely correlated with that of the time interval and is one which every man must decide for himself by experience, as the number will vary widely under different conditions. In the large Delta plantations, where the majority of the work has been conducted in the past, it has been found that weevil control throughout the season in the cuts most heavily infested and requiring the earliest treatment in the spring has necessitated from four to six applications with a time interval of one week. Other cuts more distant from hibernation quarters and thus more lightly infested required three, two, one, or no applications. In two years' work on thousands of acres handled on this basis, the average number of applications for all cotton acreage involved has been something less than two. Where infestation is more uniformly distributed at the outset and general poisoning is necessary, it has been found advisable to figure on an average of about four applications, and in case of an excessively rainy season, five or six applications. These figures are based on a one-week time interval, as this interval has been the one adopted in the majority of work so far. With a shorter time interval, however, control can be secured with about three applications. This office is now planning to open a number of small experiment stations in nearly all representative districts of the cotton belt. By conducting control tests at all of these at the same time it will soon be possible to designate much more definite rules of procedure under the varying conditions found in these different districts.

TIME TO STOP POISONING.

The time to stop poisoning has been more or less covered by the discussion of the number of applications but it is probably well to outline briefly the conditions governing this. The idea is to maintain weevil control below the point of loss to the crop long enough for the plants to set as many bolls as they can mature and also to protect these beyond the danger of weevil puncturing. Furthermore, there is nearly always a time when the plants cease to retain any more fruit. In many cases they not only discontinue squaring and blooming but shed the young bolls as fast as they are

formed. This usually means that the plant has reached the limit of its ability to mature fruit. Naturally there is no advantage in attempting to protect these forms, and poisoning during this period, if conducted after the retained bolls are sufficiently large to escape weevil injury, is bound to be profitless. The time when this condition is reached varies widely with the season as well as with the soil fertility, and these factors must always be taken into consideration in deciding whether additional poisoning is justified.

EFFECT OF RAIN ON AN APPLICATION OF POISON.

The effect of rain upon the application of calcium arsenate is a subject of much importance. Experience has shown that a certain amount of rainfall is desirable during the poisoning operations as it induces the formation of dew, makes conditions more nearly ideal for dusting, and apparently increases the amount of mortality secured from the applications. Poisoning operations have been conducted during periods of extreme drought when there was almost no dew formation, but under such conditions it has been very difficult to secure a thorough degree of control. On the other hand, excessive rain is detrimental, owing to the difficulty of getting the poison to stay on the plants long enough to control the weevils. This was especially true during some of the work in the extreme southern districts in 1919. The rains encountered in this work were excessive and in many cases occurred almost daily. Under such conditions weevil poisoning can easily become an absolute impossibility but, as far as that is concerned, such conditions make it practically impossible to raise cotton at all.

It has been found that when an application is made under unfavorable conditions and the plants are dry, even a slight shower occurring a short time later will wash off practically all the dust, while if conditions during the application are more favorable for a large quantity of the poison to adhere to the plants, a much heavier rain will not interfere seriously with the effect of the treatment. As a general rule it seems advisable to repeat an application immediately if a drenching rain falls within 24 hours after treatment. Until more information is secured on the subject, it undoubtedly will be best to follow some such rule as this, but the question of degree of weevil infestation and the conditions under which the application has been made should undoubtedly be considered in connection with the question of whether the application should be repeated.

STARTING POISONING IN THE PRESENCE OF A COMPLETE INFESTATION.

Many farmers make no move toward weevil poisoning until the crop is seriously infested and in fact almost totally destroyed by the

weevils. Then they want to get action immediately and desire to make a hurried purchase of calcium arsenate and dusting machinery to try to save the situation.

To secure control after the weevils have become excessively numerous and have punctured nearly all of the fruit is very difficult and usually involves the use of excessive dosages of poison at short intervals and, furthermore, requires an unusually large number of applications. Consequently the operation is very expensive at best and is also exceedingly hazardous. A very short delay under such conditions is extremely dangerous. The writers do not advise anyone to start poisoning under such conditions with a view of protecting the plants sufficiently to *permit the setting of a new crop.* Sometimes a certain amount of poisoning under such conditions is extremely profitable, as, for instance, when a fair crop of young bolls has been set but is still in danger of weevil attack, owing to the fact that the bolls have not yet developed beyond the point of injury. When the weevils become excessively abundant in such a crop they quite frequently not only overtake the square formation but also destroy a high percentage of the bolls, and poisoning at this time will often save the bolls which are already present on the plants. Since these bolls require protection for only a very short period, it is possible to make perhaps two applications under such conditions and thus retard the weevils sufficiently to eliminate injury to the bolls. It should be remembered, however, that this is quite a different proposition from starting in and attempting to control the weevils to the extent of permitting new squares to develop, bloom, form bolls, and reach maturity.

EARLIER SEASON TREATMENT OF ISOLATED INFESTATIONS.

The expense of weevil poisoning can be considerably reduced in many cases by localized treatment of the most heavily infested patches early in the spring. Often only a few acres in a large field will be infested early in the season. These may be distributed along a strip of timber or may adjoin barns, cabins, or other hibernation quarters. The weevils tend strongly to attack the largest plants available on emergence in the spring, and in case of any inequalities of soil fertility such as are very commonly found, it will generally be noted that the weevils will concentrate on the patches of larger cotton. Under any such condition it is often possible greatly to reduce the infestation of the entire field and to delay considerably the date of general poisoning by going into these isolated spots fairly early in the season and treating them thoroughly before the weevils have an opportunity to spread.

ORGANIZATION OF POISONING OPERATION.

The organization of the poisoning operation will differ considerably with variations in the size and type of the farm involved, but in general may be roughly classified into three groups: First, the large plantation operation where the poisoning is conducted by a separate organization on a wage basis, all crops being treated regardless of tenantry; second, the operation on a large plantation where the treatment of each crop is left to the individual tenant; third, the operation on the small farm where all the poisoning is conducted by the owner and his laborers.

The majority of the work which has been conducted by this department has been located on large plantations which are operated on a tenant basis. Under this form of operation each tenant is in a way an independent farmer in that he has a particular crop for which he is responsible, but at the same time he is operating under the direction of the plantation manager and deriving more or less support from the plantation, paying as a rule a certain proportion of the crop yield in lieu of rental. This condition complicates the poisoning situation. Some planters desire to purchase small-scale machinery for each tenant, leaving the treatment of his crop to the tenant and making this a part of the regular farming operations. Theoretically, the planter would seem by this arrangement to get the work done for nothing. In reality, however, the tenant's time is so fully occupied by his regular duties that he can conduct such work only by neglecting other necessary operations. Furthermore, it has generally proved impossible to get the operation properly conducted if left to the individual tenant. This not only means that the opportunity for weevil control is lost on their crops but that these fields become a menace to the adjacent cotton which may have been properly poisoned. *Weevil poisoning is a plantation and not an individual field proposition.* For this reason nearly all the dusting work which has been done in the past has been organized separately from the regular routine operations of the plantation. Separate labor is secured and assigned to the poisoning operations and applications are made regardless of tenantry or crop arrangement, and are based purely on the distribution of the weevils over the place. This calls for skillful supervision, and where the property is large, involving the use of a considerable organization, it is generally found advisable to employ a competent man to take charge. This arrangement is particularly desirable at the present time, since the operation is so new and there is still so much to be learned about the most economical means of procedure.

The farmer who cultivates his own crop, or at least does so to a considerable extent, is in much closer touch with the progress of

events on his place and has a much smaller area to consider. Under such conditions he can watch his cotton very thoroughly for weevil outbreaks and is usually fully informed on weevil distribution and abundance throughout his fields. Furthermore, under such conditions poisoning is a comparatively minor operation, and by the use of hand guns or small-capacity traction dusting machinery it is possible for him to fit the weevil-poisoning work into his regular operations and handle it with little or no interference. Of course, as a rule, his fields are smaller than on a large plantation and thus it is usually necessary for him to poison his entire crop.

In a number of instances several neighbors have planned to enter into some agreement and purchase a traction-power machine cooperatively with the idea of treating their several crops with the same machine. Theoretically this arrangement seems a very good one, but there is considerable room for doubt concerning its practical working. As has been pointed out, weevil poisoning is generally an emergency proposition and the work must be done at the right time or the entire operation may be imperiled. Consequently, the situation which would develop in case the weather should interfere with a set schedule for machine operation on several places can easily be imagined. Crops belonging to the different men would require treatment at the same time and it would simply be contrary to human nature if friction did not develop under such conditions.

DUSTING MACHINERY TO USE.

The selection of proper dusting machinery is undoubtedly equally as important as securing the correct poison. At the outset of the poisoning work an attempt was made to utilize or adapt existing types of dusting machines such as have been used for truck crops or orchard dusting, but it was soon found that cotton dusting required highly specialized machinery. All dusting operations which had been conducted previously had been in conjunction with more or less intensively handled crops where the labor supply per acre was generally rather plentiful and where the labor was of a fairly intelligent type. In the culture of cotton, however, dusting is placed on an extensive basis where it becomes a large field operation and the machinery must be made as efficient, fool-proof, and simple as possible.

The success of cotton dusting is so dependent on thorough distribution of the poison that any attempt to utilize a means of application which does not give this thorough distribution is certain to result in absolute failure. Many farmers have been accustomed to use the "bag-and-pole" method of poisoning for leafworm control. Such a method of application is suited to leafworm control where large

areas of plant tissue are devoured by the insects and the chances of poisoning considerably increased, but it will not furnish a sufficiently thorough distribution to result in control of the boll weevil.

A special Farmers' Bulletin (1098) has been issued by the Department of Agriculture on the subject of dusting machinery for the cotton boll weevil, and everyone contemplating poisoning is advised to secure a copy of this and study it thoroughly.

So far only three types of satisfactory dusting machines have been developed and placed on the market, namely, the hand gun, the wheel-traction machine, and the engine-power machine.

HAND GUN.

Several satisfactory models of hand guns are now on the market and may be purchased at from $15 to $25 each. Each machine consists of a small hand-operated fan and hopper slung from the shoulder of the operator, which is carried through the field, poisoning a single row of cotton at a time. Unfortunately these machines are very difficult to operate. The labor involved is strenuous, to say the least, since the operator must walk through the field at a very fair pace and bear the strain of carrying, directing, and cranking the machine. It has been found that operating for a short period of time, a man can cover about an acre an hour with one of these guns, but he can not continue at this rate for more than an hour or so. Owing to the necessity of poisoning when the plants are moist with dew, hand-gun work can usually be conducted only during the early morning or late evening. Generally speaking, this means from about 4 or 5 o'clock until 8 or 9 in the morning, and from about 6 o'clock to dark in the evening. About the best speed that can be attained is in the neighborhood of 5 acres per day for each man. If two men are available for each gun, it is possible to change occasionally and thus speed up the work so that the area covered by the single gun during the day is somewhat increased, but even under such conditions it is hardly safe to count on an average of more than 5 acres per day for each machine. Figuring on a four-day time interval, this would mean that each machine would cover about 20 acres, but in reality, with loss of time due to various causes which is certain to be experienced, and with delay due to inability to operate under unfavorable conditions, it is certainly not safe to figure on an average allotment of more than 15 acres to each hand gun. It would undoubtedly be much better to figure on about 10 acres for each hand gun, and, if possible, to distribute the operation of this gun between two different laborers.

In many cases farmers planting from 40 to 100 acres of cotton do not feel justified in purchasing large machines and desire to under-

take weevil poisoning by the use of a number of hand guns on this area. This has generally proved very unsatisfactory. The labor requirements of the guns are so great and the operation so laborious and difficult that labor troubles are certain to develop under any normal condition and this has generally resulted in preventing anything like a satisfactory schedule for poisoning work.

One important use of the hand gun is in conjunction with power machinery. A great many fields have certain portions which are very difficult to treat with power machinery, owing to the presence of ditches, stumps, short rows, or similar obstacles. Attempts to treat these portions of the fields with large machinery greatly reduce the rapidity of the operation of the machine and frequently the cotton is injured by being tramped and driven over. Under such conditions the efficiency of the large machine is much increased if a few hand guns with which to treat these difficult portions are available for use at intervals.

Hand guns are also of great value for the early-season work in treating isolated spots of infestation which are often comparatively small in extent. In much of the work which has been conducted in the past, hand guns have been used in such fields for the first application or two and a sufficient degree of control secured from this work to make it possible to defer starting general poisoning with a large machine until some weeks later than would otherwise have been the case.

Several instances have been noted where hand machines have been offered for cotton dusting purposes with the distributing system divided between two nozzles, the idea being that two rows could be treated at each trip. None of the machines manufactured at present have more than enough fan power to treat a single row satisfactorily.

A number of hand guns have been offered for use in cotton dusting with the blower constructed so that the dust delivery is intermittent. As such guns are usually equipped with a bellows serving as a blower the powder is expelled only in recurrent blasts. These are not satisfactory for cotton work since it is necessary that the gun discharge the dust continuously in order that uniform poisoning of all plants be secured while the operator proceeds along the row.

As has been stated, hand-gun work is mainly conducted in the early morning and late evening, and this limits very much the amount of territory which can be covered each day. Operation during the night, however, is often entirely feasible and the results from such operations are usually better than where treatments are attempted during the day. Very satisfactory hand dusting can be done at night by the aid of a small oil or carbide light attached to the hat of each operator, or, in some cases, several hand guns may be

worked together as a group if some kind of torch or contractor's flare is placed at the row ends to provide light.

Another way of reducing the amount of labor involved in hand dusting is by the operation of the machine from muleback. This has been tried on numerous occasions and is generally much more satisfactory than by walking.

POWER DUSTERS.

The earliest work on weevil poisoning was conducted entirely with hand guns, as very small areas were treated during the strictly plat-test stage of the work. Ordinarily the next step in development of dusting machinery would have been to produce something of slightly larger capacity, but owing to the rapid development of the work at this stage, attention was transferred from the development of hand guns to that of blowers of the largest possible capacity, namely, the engine-power machines. In this case the duster was a horse-drawn machine with the fan and feeder operated by a small gasoline engine mounted on the platform. This machine had a distributor extending across the rear end with five nozzles spaced $4\frac{1}{2}$ feet apart, thus covering approximately five rows. Several models of these machines were devised and placed on the market and were used rather extensively during 1918 and 1919. It was found that they would cover from 6 to 10 acres an hour while in operation but that the loss of time due to mechanical difficulties was so great that a machine seldom averaged over 40 or 50 acres for the day's operations. Continued use of these machines soon made it obvious that they were too complicated and cumbersome to be thoroughly satisfactory for cotton-dusting work. Probably the most serious difficulty was the gasoline engine. Another great difficulty was found in constructing a thoroughly satisfactory distributing system for spanning five rows. There was considerable length of pipe extending out beyond the machine on both sides and as this was necessarily made very heavy, the weight caused almost constant breakage due to excessive vibrations and jarring. In many cases the distributors of these power dusters were cut off so as to cover only three rows at a time and they really treated more acreage throughout the season than when they were arranged to span five rows, owing to the greater convenience in handling the machine over the field, around stumps, fences, etc., and the decreased loss of time from breakage.

These power machines were placed on the market at prices ranging from $400 to $600 and this price seemed high for the work they could accomplish. Consequently it was desirable to devise a machine which would eliminate the gasoline engine and span only three rows

with its distributor and which could be sold at a more reasonable price. The only answer to this problem which has been developed so far is the wheel-traction or cart type of duster.

WHEEL-TRACTION OR CART DUSTERS.

For the wheel-traction duster a light two-wheel cart is utilized and the power for driving the fan, feeder, etc., is derived from the wheels of the cart. This duster is pulled by two mules and is operated by one man instead of two. By the beginning of 1919 a tentative model had been produced which was placed in the field and operated on a practical basis throughout that season. This machine proved eminently satisfactory in spite of the fact that it was very crudely constructed, and it was selected as the most desirable type for general use in cotton dusting on a large scale. As built, it proved far simpler and easier to operate than the power machines and was especially valuable for its convenience in driving through the field. A number of duster manufacturers became interested in this type of machine and several models based somewhat on this idea are now on the market and others are in the course of construction. These differ widely and embrace the ideas of individual designers, but the general principles of construction are more or less the same. Practically all of the machines are built with an arched axle providing a 42-inch clearance beneath the arch and having a tread of about 48 inches, thus enabling satisfactory operation in any cotton rows not narrower than about 36 inches.

It has been found that under normal conditions one of these wheel-traction machines will probably average about 25 acres per night of operation. It may exceed this amount under very favorable conditions but it is not safe to figure on a greater average than this. As has been pointed out, it is undoubtedly desirable to provide equipment for treatment at a time interval of about 4 days. Owing to rains and other interruptions, it is undoubtedly not safe to figure on more than three days' operation out of the four. Consequently, about the best that can be expected of one of these machines is that it will handle in the neighborhood of 75 acres of infested cotton throughout the season.

So far the machines of this type which have been built have been placed on the market at a rather high price, ranging from about $350 to $500. The manufacturers have taken extreme precautions to place the highest quality of workmanship and material in the construction and this has resulted in making the price of the machine higher than is generally desirable. It still remains to be seen whether or not this cost is justified by increased efficiency of the machines. It seems quite probable that other machines built on

much the same design will be placed on the market at a fairly early date at a lower figure. From present prospects the minimum sales price for such a machine will be in the neighborhood of $200.

The high cost of this machinery is particularly unfortunate, as it will tempt the farmer to expand his acreage allotment for each machine as much as possible by increasing the time interval between applications. This is bound to be a hazardous practice. In fact, if a grower is confronted with the problem, it would be far better for him to select a limited acreage of his best yielding land where the weevil damage is highest and treat this thoroughly and properly, ignoring the rest of his crop, than risk the success of the entire operation by attempting to make a machine cover too much acreage.

NEED OF AN INTERMEDIATE TYPE OF DUSTING MACHINE.

As the situation now stands, there is no dusting machine on the market intermediate between the hand duster and the wheel-traction or cart type of duster. Inasmuch as hand dusters are generally unsatisfactory on fields larger than about 25 acres, and as the cost of a cart duster is such that a man is seldom justified in buying one for use on less than 75 acres, no equipment suitable for a man cultivating between 25 and 75 acres of cotton is available and his problem is a difficult one. When a sufficient supply of labor is available, however, it may be possible for him to utilize hand guns; and where the soil fertility is particularly high, the purchase of a cart machine for use on the small acreage may be justified. Several types of devices, such as saddle guns or single-wheel machines for operation between the cotton rows, are being studied, but the process of perfecting and producing them will require considerable time.

LIGHTING EQUIPMENT FOR DUSTING MACHINES.

The question of lighting any cotton-dusting machine requires particular attention. As has been explained, an application of poison gives the best results when it is made at night; therefore a thorough lighting equipment must be provided. This has been a serious difficulty in the past and all kinds of lights have been tested. So far only one type has been developed which gives any assurance of being thoroughly satisfactory. This is a special model of acetylene light which utilizes a compressed carbide cake for fuel. These lights have been constructed for cotton-dusting machine work and apparently the majority of the machines to be placed on the market will be equipped with them. At any rate, anyone purchasing a dusting machine should be sure that it is provided with a simple and satisfactory equipment that will give ample light for avoiding stumps,

ditches, etc., while driving. It must also afford sufficient rear illumination over the nozzles to enable the operator to make sure that the dust flow is regular.

CAPACITY OF MACHINES FOR TREATING SEVERAL ROWS PER TRIP.

In the earlier stages of the work it was attempted to make machines with adjustable nozzles that could be aimed directly at the rows being treated. It was soon found, however, that cotton rows vary so greatly in spacing that such an arrangement was impractical. Moreover, it was unnecessary. The entire poisoning operation is based on the plan of creating a thick cloud of dust which will envelop all parts of the cotton plants and coat them thoroughly. Consequently, all width-adjusting devices were eliminated and the nozzles have since been spaced about $4\frac{1}{2}$ feet apart. These nozzles are provided with deflecting plates or some similar spreading device which causes the dust clouds from the different nozzles to unite very quickly after leaving the machines, so that a uniform "fog" extending from row to row is created. Under such conditions it does not matter whether the nozzles are directly over the rows or between them. It has also been found possible under certain conditions to cover more rows than the nozzles actually span. This suggestion, however, should be taken very conservatively, as considerable experience is required in the use of dusting machinery to determine just how far the drift can be considered as thoroughly effective in dusting. Until the operators have become thoroughly experienced in this work it is probably the best plan to figure on taking only as many rows as the distributor will actually span.

FEATURES TO BE NOTED IN PURCHASING COTTON-DUSTING MACHINERY.

For the benefit of those planning to purchase cotton-dusting machinery, the following brief outlines have been prepared giving the most important features which should be considered in order to make sure that the machines will be satisfactory.

HAND GUN.

The total weight should be not over 20 pounds when filled with poison dust.

The hopper should hold about 4 to 7 pounds of calcium arsenate and it should be possible to put out practically all of this before refilling.

The balance of the gun should be such as to cause the least strain on the operator, that is, the heavy parts of the machine should be as close to his body as possible.

The gun should hang naturally so that the nozzle is directed at the tops of the cotton plants without causing any undue strain on the operator in aiming it.

The capacity of the feeding mechanism should be sufficient to permit the use of a delivery of at least 1 pound in 5 minutes at the ordinary rate of cranking.

The feed should be quickly and positively controlled. Adequate facilities should be provided for lubrication of working parts.

The fan should create sufficient air current to break up the dust into a cloud and force it to spread over all parts of the plant.

The gun should be well constructed throughout so that breakage is reduced to a minimum.

All parts of the gun should be as conveniently accessible as possible for repair or replacement.

WHEEL-TRACTION OR CART DUSTER.

The wheel-traction machine should be light enough in weight and draught to enable an average team to operate it through a full night without undue fatigue.

There should be sufficient axle clearance to avoid plant injury.

The tread should be such that it will straddle a row of cotton without running on the adjacent ones and still prevent the machine from being dangerously top-heavy.

The machine should be properly balanced on the axle to prevent uptilting of the tongue or undue strain on the necks of the team.

All details of construction should be simple, fool-proof, and durable.

The feed mechanism should be subject to quick and positive regulation, varying from a complete cut-off to a maximum delivery of 6 pounds in 5 minutes through the three nozzles at the ordinary rate of walking for the team.

The fan should create sufficient air blast to prevent clogging of the pipes, and to blow the dust throughout the plants under any ordinary weather condition.

The machine should be provided with suitable lighting equipment.

The hopper capacity should be sufficient to hold from 30 to 50 pounds of calcium arsenate.

The distributing system should be provided with a positive lift to regulate the height of the nozzles from vertical to horizontal and should also be arranged to fold in conveniently to permit passage through gates.

The platform should be large enough to accommodate all machinery and the driver and also to carry a barrel of poison.

The driving mechanism should be so arranged that the fan will continue in operation while the machine is turning on one wheel in either direction at row ends.

The running and driving mechanism should be shielded to prevent plant injury or clogging with vegetation.

The method of hitching should allow flexibility which will prevent the load from being thrown on one animal.

All parts should be readily accessible for repair or replacement.

POWER DUSTER.

The engine of a power duster should be as simple and efficient a type as possible and should provide a slight surplus of power over that actually required to operate the machinery.

The truck should be provided with a fifth wheel arrangement and the front wheels should cut under the body to permit short turns.

The distributor construction should be strong enough to carry the wide spread of nozzles.

COST OF POISONING.

Anyone who has read the preceding pages carefully can easily appreciate the futility of attempting to give generalized figures on the cost of poisoning which would be of any value to the individual. The cost to each man is going to be an individual problem and will differ radically in the different fields and in different seasons. Although careful cost figures have been kept in connection with the experiments which have been conducted in the past on both large and small scale work, it is useless to give more than a few generalized statements concerning these. Where the operation has been conducted on an individual field basis requiring in the neighborhood of four applications, it has been found that the cost of poison, labor of application, and reasonable depreciation on the investment for machinery has been in the neighborhood of $7 to $10 per acre for the season. On a large plantation basis the investment in poison and machinery has naturally been lower but the additional cost of supervision, etc., has generally been sufficient to offset this difference. At present prices, it is hardly safe to figure on a cost of less than $2 an acre per application.

GAINS TO BE EXPECTED FROM POISONING.

The gain in amount of seed cotton to be expected from the use of poison is another point which is not subject to definite figures. During the past five years several hundred plat tests have been conducted in such a manner that an accurate comparison in yields was

afforded between the poisoned and unpoisoned plats. Throughout this work the gains have varied from nothing to over 1,000 pounds of seed cotton per acre.

The most that can be expected of poisoning is the elimination of weevil injury. Soil fertility is very important and really becomes the determining factor in the amount of gain which can be secured from the poisoning. One interesting feature of the work which has been conducted so far is the large number of tests on fields which had a fairly low degree of weevil infestation and which have shown absolutely no gain from the operation. In many cases comparable plats have been selected and started with an infestation of 10 or 15 per cent, one plat being poisoned and the other left unpoisoned as a check. In such cases, the infestation of the check plat, instead of increasing as would normally be the case, has been held in check by some climatic condition so that there was only a gradual increase to a maximum of from 35 to 50 per cent of the squares punctured at the end of the season. Usually, under such conditions, no gain in yield is shown in spite of the fact that infestation of the poisoned plat was practically wiped out. In other words, the degree of infestation in the check plat was not sufficient to overtake the normal shed of squares and thus there was no reduction in crop yield. This, of course, illustrates the needlessness of poisoning unless the weevils are sufficiently abundant to injure the crop.

There are many fields where weevil infestation becomes so complete by the middle or latter part of the summer that it would seem advisable to start poisoning, but the plants in these fields may have reached the limit of their production on that soil, thus being unable to take advantage of any protection from weevil attack. This is particularly true of many of the sandy soils upon which the plant produces a very quick crop of cotton and then matures and stops fruiting at an early date. This point is further complicated by variations in the habits of the different cottons. For example, certain varieties of cotton have what is ordinarily termed a "determinate" growth. They make their crop early and then stop fruiting altogether. Consequently, any poisoning under such conditions, regardless of the degree of weevil control secured, is a useless expense unless undertaken for the protection of the young bolls already set on the plants.

In still other cases there are soils of such low potential productivity that even if the entire crop were saved from destruction by the weevil its value would still not justify the expense of poisoning.

To summarize the results of the experiments which can be considered of real value in this connection, it may be said that the actual gains in seed cotton per acre have ranged from about 200 to 1,000

pounds. In these cases the infestation was heavy enough to justify the treatment, and, furthermore, the soil was generally of a decidedly fertile nature. In reality these figures are quite conservative, as they are based on very small plat tests where there was undoubtedly considerable reduction in gain due to the effect of weevil migration from nonpoisoned cotton. This is shown by the general results of a considerable number of the large-scale tests conducted under conditions more or less the same. Unfortunately in large-scale tests accurate figures can not be secured on the increase of yields, but it is obvious from the approximate comparisons made that the gains were very large, being, in fact, considerably larger than those obtained in plat tests under the same conditions. Consequently it seems safe to assume that with fertile soil and a fairly severe weevil infestation average gains of 500 pounds or more of seed cotton per acre are not at all remarkable.

ADVISABILITY OF POISONING UNDER PRESENT CONDITIONS.

The first thing which must be decided by any one contemplating poisoning is whether or not his conditions are such as will enable the operation to be profitable. In case of doubt it would be best for him to forego poisoning. As has been shown, weevil infestation must necessarily be at least fairly severe. Furthermore, the soil fertility must be such that the plants can take advantage of the protection afforded them by poisoning and produce a considerable gain in yield. It is difficult to establish any fixed limits with regard to soil productivity, but for the present at least it hardly seems advisable to attempt poisoning unless the land would make at least half a bale of cotton per acre in case there were no weevils. In fact, if the higher-priced machinery, such as has been mentioned, is utilized, it will probably be advisable to raise this limit somewhat and poison only land capable of making two-thirds or three-fourths of a bale of cotton. This naturally means that a very large proportion of the hill-land cotton will not justify poisoning at present, as the soil fertility is too low. Nearly all hill farmers, however, have at least a few acres of fertile bottom land in their farms which can be utilized for small-scale poisoning work during the first year or two to afford experience in poisoning which will make it safer for them to expand the work later over the remainder of their crop. In fact, regardless of conditions, unless a man is thoroughly sure of being able to conduct the operation just as outlined, it is undoubtedly best for him to undertake it first on only a portion of his cotton, selecting for this purpose the most fertile soil which is subject to the heaviest weevil injury.

A very accurate check plat should be provided; otherwise the question of gain or loss is likely to be more or less problematical. For this purpose several fairly uniform cuts should be selected, subject to about the average degree of weevil infestation in that locality, and only one-half of each cut treated, letting the remainder go untreated as a check on results secured. A little experience of this sort will soon make clear the conditions under which the grower can or can not poison profitably. Of course, this unpoisoned check plat will serve to increase the infestation of the adjacent poisoned cotton, but this slight loss will be far more than offset by the value of the information secured.

Weevil poisoning has in some cases been criticized as possibly tempting the farmer to neglect securing the proper varieties of cotton and cultivating properly, and other important factors or operations which have been learned as a result of hard experience with the boll weevil. On the contrary, by eliminating weevil injury it should encourage the planter to strive for the increased yield which can be induced by good farming, and to emulate the man who practices such a good method of farming that his gain from weevil poisoning is tremendously increased. *No one should slight any other operation involved in the production of the cotton crop just because the plants are being poisoned.* Weevil poisoning can not make cotton. It is up to the farmer and the land to do this, and the best that can be expected of poisoning is to save this cotton from weevil destruction.

CONTROL OF THE COTTON LEAFWORM AND FALL ARMY WORM WITH CALCIUM ARSENATE.

One question which frequently arises in connection with the use of calcium arsenate is whether or not this material will control the cotton leafworm, fall army worm, or any other pests of this nature. It will undoubtedly be as satisfactory for this purpose as any chemical which could be utilized. It is very nearly as poisonous as Paris green to the worms and has the decided advantage of being cheaper and less injurious to the plants. In case anyone desires to utilize weevil-poisoning equipment solely for leafworm control, however, he should bear in mind that he could considerably reduce the expense of the operation without interfering with its effectiveness by mixing equal parts of lime and calcium arsenate and applying this mixture at the rate of about 4 or 5 pounds per acre.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTS AFFECTING COTTON PLANT.

AVAILABLE FOR FREE DISTRIBUTION.

Cotton Improvement under Weevil Conditions. (Farmers' Bulletin 501.)

Fall Army Worm, or "Grass Worm," and Its Control. (Farmers' Bulletin 752.)

Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)

Red Spider on Cotton and How to Control It. (Farmers' Bulletin 831.)

Bollworm or Corn Earworm. (Farmers' Bulletin 872.)

How Insects Affect the Cotton Plant, and Means of Combating Them. (Farmers' Bulletin 890.)

Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. (Department Bulletin 233.)

Studies of the Mexican Cotton Boll Weevil in the Mississippi Valley. (Department Bulletin 358.)

Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.)

Cotton Boll Weevil Control in the Mississippi Delta, with Special Reference to Square Picking and Weevil Picking. (Department Bulletin 382.)

Collection of Weevils and Infested Squares as a Means of Control of the Cotton Boll Weevil in the Mississippi Delta. (Department Bulletin 564.)

Pink Bollworm with Special Reference to Steps Taken by the Department of Agriculture to Prevent Its Establishment in the United States. (Department Bulletin 723.)

Recent Experiments in Poisoning Cotton Boll Weevils. (Department Bulletin 731.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C.

Use of Paris Green in Controlling the Cotton Boll Weevil. 1904. (Farmers' Bulletin 211.) Price 5 cents.

Controlling the Boll Weevil in Cotton Seed and at Ginneries. 1904. (Farmers' Bulletin 209.) Price 5 cents.

Miscellaneous Cotton Insects in Texas. 1905. (Farmers' Bulletin 223.) Price 5 cents.

Control of the Cotton Boll Weevil. 1912. (Farmers' Bulletin 500.) Price 5 cents.

Boll Weevil Problem with Special Reference to Means of Reducing Damage. 1917. (Farmers' Bulletin 848.) Price 5 cents.

Recent Studies of the Mexican Cotton Boll Weevil. 1914. (Department Bulletin 231.) Price 5 cents.

Studies on the Biology of the Arizona Wild Cotton Weevil. 1916. (Department Bulletin 344.) Price 5 cents.

Red Spider on Cotton. 1917. (Department Bulletin 416.) Price 20 cents.

Mexican Cotton Boll Weevil. 1897. (Entomology Circular 18.) German and Spanish editions, each 5 cents.

Most Important Step in Control of Boll Weevil. 1908. (Entomology Circular 95.) English and French editions, each 5 cents.

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